

LARRACAS

An Experimental Water
Purification Plant and its Results

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**AN EXPERIMENTAL WATER
PURIFICATION PLANT
AND ITS RESULTS**

BY

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

MUNICIPAL AND SANITARY ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FIDEL VIDAL LARRACAS

ENTITLED AN EXPERIMENTAL WATER PURIFICATION PLANT AND ITS RESULTS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Municipal and Sanitary

Engineering

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INTRODUCTION.

All natural waters contain more or less foreign matters either in suspension or in solution, and the degree of purity is dependent on the locality. These foreign matters may be divided into three classes: (1) The corrosive impurities, such as sulphate of iron (FeSO_4), carbonic acid (H_2CO_3), etc. (2) The scale-forming impurities, such as iron carbonates $\text{Fe}(\text{HCO}_3)$, calcium carbonate CaCO_3 , etc.. (3) The alkaline impurities, such as potassium and sodium carbonates Na_2CO_3 and KCO_3 . All of these are more or less detrimental to boilers, pumps, valves, and water pipes.

The University of Illinois water supply which is drawn from the same geological formation as that of Champaign and Urbana is no exception to the above. Prof. Bartow, Director of the State Water Survey, and Mr. Lindgren of the University of Illinois in their paper entitled "Some Reactions During Water Treatment" have shown that the University water supply presents "a variety of unsatisfactory features, viz: turbidity on exposure to air, sediment varying in color from black to red according as the amount of oxidation of iron salts varies; trouble from crenothrix in the water mains; soft-scale, clogging the feed pipes of boilers and trouble in dairying and photography". On account of this unsatisfactory condition the importance of



improving the University water by some treatment is evident. It is the object of this thesis to aid by experiment in determining the best method of removing some (if not all) of the impurities named above such as, for example, iron, calcium carbonates, turbidity, hardness, alkalinity and color by the use of mechanical filter with the aid of a coagulant. For convenience, the whole subject will be treated into four different parts, namely:

(1) Theory.

(2) Description of the Experimental Plant.

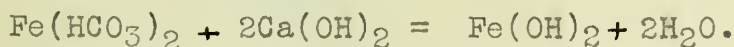
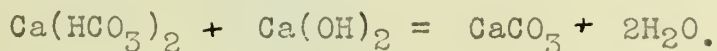
(3) Operation and Results of Tests.

(4) Conclusion.

(1) THEORY.

The carbonates and iron in water may be removed or greatly reduced by coagulation, sedimentation and filtration. The use of a chemical as a coagulant enables the filtration to be carried at higher rate yet with greater efficiency. The coagulant with the water forms a gelatinous precipitate which not only subsides much more quickly than the suspended matter ordinarily contained in the raw water but from its sticky gelatinous nature it has the faculty of collecting and carrying down the suspended matters in it.

Caustic lime is the only chemical that was used in connection with the experiment, and this lime was in the form of saturated lime water ($\text{Ca}(\text{OH})_2$). This acts upon the carbonates of lime, and magnesium (if there is any) which are in solution in the form of bicarbonates. These substances react with the soluble bicarbonates to form insoluble carbonate of lime (and hydrate of magnesia); and carbonates of iron will be precipitated as hydrate of iron. Some of the reactions that take place are:



The paper before referred to by Prof. Bartow and Mr. Lindgren gave 4 stages of reaction taking place. " During the 1st. stage the reaction is between the calcium hydroxide and free ^{the}

carbon dioxide. At the second stage, the calcium hydroxide reacts with the calcium acid carbonate. In the third, the calcium hydroxide reacts with the sodium bicarbonate, and in the fourth the calcium hydroxide reacts with the magnesium bicarbonate."

2. THE EXPERIMENTAL PLANT.

The experimental plant as shown on plates 1, 2, 3, 4, and 5 consists of two lime water mixing tanks and one lime water controller tank, one raw water supply tank, one sedimentation tank, one rapid filter and one filtered water tank.

Raw water supply tank.-This tank is made of galvanized iron and is circular in form, four feet in diameter and two and one half feet deep, with a capacity of 235 gallons. This tank is located on an elevated platform about eight feet above the floor, close to the east side wall of the laboratory room. The head of water in this tank is regulated by a float valve, and the supply may be entirely cut off or regulated at will by a hand valve on the outlet from the tank.

The influent and effluent pipes are both of one inch diameter, the former leading from the pumping room thru a covered wooden conduit to the supply tank, and the effluent from this tank thru the room about seven feet above the floor to the sedimentation basin.

Lime water tanks:- Branches from the supply main to the raw water tank lead to two lime water mixing tanks which are

made of #22 galvanized iron, and of different sizes. One, circular in form, is four feet in diameter and two and one half feet in depth, with a capacity of 235 gallons and is located directly above the other which is also of circular form, six feet in diameter and three feet deep, with a capacity of 625 gallons, and located on the same level as the raw water supply tank. Pipes lead from each of these two tanks to the lime water controller. This is square in form, its dimensions being two feet side and one and one half feet deep with a capacity of 45 gallons, and is provided with a float valve which regulates the head of lime in it. A one-half inch effluent pipe connects it at one inch above the bottom of same to the effluent pipe from the raw water tank.

Sedimentation Tank:- The sedimentation tank, rectangular in shape, is 15 feet long, 7 feet wide and 3.85 feet deep, made of wood lined with tin, and having a capacity of 2950 gallons. A slotted wooden baffle is placed across the tank at one and one-half feet from the inlet end, and one wooden weir one-half inch thick and 42 inches deep at one foot from the outlet end.

The inlet pipe enters the basin from above ending one and one-half feet from its top and is provided with a float-valve. The outflow pipe is located at the other end and at about two inches from the bottom of the tank.

Filter:- The mechanical filter as shown on plate 5, is made of # 18 galvanized iron 20 inches in diameter and nine feet in depth. The bottom is provided with a drainage system consisting of a two inch main collector with five one inch laterals and 19

mechanical filter strainers obtained from Pittsburgh Filter Manufacturing Company. The filter is provided with wash water and air pipes which connect to the strainer system and which may be shut off or opened by means of hand valves. The air is piped from the boiler room and is under 30 pounds pressure. The wash water is drawn from the University supply under pressure. An overflow pipe is provided at one foot above the surface of the sand to discharge the wash water. The head of water is regulated by a float valve connected to the influent pipe. Two glass-gages are provided to measure the loss of head, one connected to the filter above the sand and the other connected to the effluent pipe close to the filter.

The total thickness of sand is 51 inches composed of the following layers:

12 inches of one fourth to one-half inch gravel.

6 " of $\frac{1}{16}$ to one fourth inch gravel.

33 " of sand.

The latter material came from Redwing, Minnesota, and has an effective size of .43 m.m. and a uniformity coefficient of 1.51. this size is somewhat coarser than that ordinarily used in filtration plants, and the uniformity coefficient is low.

Filtered Water Controller:- The controller consists of a galvanized iron tank two feet in diameter and twenty-one inches deep with one inch discharge pipe from the filter, a float valve and one inch discharge pipe controlled by one inch discharge valve. The float valve maintains the head of the filtrate in the tank constant, and the gate valve regulates the rate of filtration.

5. OPERATION AND RESULTS OF TEST.

The method of operation was as follows: One of the lime water tanks was filled with water, and sufficient lime was added to make the solution saturated. The solution after settling was allowed to flow from the tank by opening the valve to the controller. While this was running, mixing of lime was done and solution allowed to settle in the other tank, so that when the former tank runs out the latter may supply the lime water. The controller is connected to the raw water pipe which leads from the raw water tank to the sedimentation basin by a $\frac{1}{2}$ inch cast iron pipe, the amount of solution used being regulated by the amount of opening of a gate valve in this pipe. This arrangement seemed to work fairly well at first, but after a few days of the experiment some difficulties presented themselves. These difficulties have, to the writer's opinion, been due to two causes: (1) the clogging of the pipes, and (2) the smallness of head from the controller. By this arrangement, successful tests were made only by constant flushing of the pipe. The above difficulties, therefore, necessitated the renovation and redesigning of the system.

The arrangement of the new system was as follows: The controller was raised three feet above its former elevation, and the lime water to it was supplied only by the upper tank, the lower tank being used as a mixer from which the lime water was pumped by a hand pump to the tank above. The amount of lime water was controlled just as before, and it flowed thru

a glass funnel to the raw water pipe. This new arrangement seemed to work fairly well, and no trouble was experienced during the experiment.

The filter was started on May first and tests continued until May 16, but no sample was taken till the 5th. The modification of the system was made after two fairly good representative samples ^{with} different amount of coagulant under the former system were taken, and this was on May 8. The coagulated raw water was estimated to remain in the tank about eight or nine hours, depending on the rate of filtration which varied from 3.7 to 4.4 gallons per minute or from 105 to 127 millions gallons per acre per day. Samples of the raw water were taken only once every time the filter was run, and they were taken several hours before those of the filtrate. The reason for taking only one sample was that the condition of the raw water thruout the experiment was practically constant as may be seen from the table number 1. Samples from the sedimentation water were taken at intervals of one hour, and usually two hours before the samples of filtrate.

All these samples were analyzed for iron, alkalinity to both phenolphthalein and methyl orange, for turbidity, hardness and color. The methods used for these analyses were: For iron, the color standard, concentrated nitric acid and potassium sulphocyanide solution as reagents; for alkalinity, phenolphthalein and methyl orange as indicators and ^N50 sulphuric acid; for turbidity, the silica standard; for hardness, the soap method; and for color, the color plates standard. The results are tabulated

on table 1 page 10.

The average loss of head at the start of the filtration was three feet and five inches, and at the close of the run was six feet and four inches.

The sand was washed in the following way: the influent and the effluent valves of the filter were closed. The air was forced thru the sand for five minutes, the pressure being regulated by the amount of opening of the valve , and then clean wash water was allowed to flow up thru the sand until the drained water from the filter appeared clear. The average length of time in cleaning was 25 minutes.

RESULTS OF CHEMICAL ANALYSES OF THE
INFLUENT, SEDIMENTATION and EFFLUENT.

TABLE 1

Kind of water	Hour of collection	Date of collection	Amt. of lime.Gr. per gal.	Rate of Filt. Gal. per Min.	Alkalinity to M.Orange. Parts per Mill.	Alk. to Phenol. Parts/m.	Turbid. Parts per Mill.	Iron. Parts per Mill.	Color. Parts per Mill.	Hardness Parts per Mill.
Raw	11:30	May 5	---	---	186.0	.00	10	39	49	407
Filtrate	4:00p.m.	"	9.17	4.36	178.0	0	0	25	0	371.5
"	8:30 "	"	"	"	160.0	0	0	30	0	371.5
"	9:15 "	"	"	"	155.0	0	0	25	0	364.4
"	9:45 "	"	"	"	155.0	0	0	30	0	364.4
Raw	5:00 "	" 7	----	----	184.0	0	10	39	49	407.0
Filtrate	3:30 "	"	11.63	3.95	152.0	0	0	20	0	300.0
"	5:00 "	"	"	"	146.0	0	0	20	0	300.0
"	6:00 "	"	"	"	150.0	0	0	25	0	307.0
"	7:00 "	"	"	"	149.0	0	0	25	0	300.0
"	8:00 "	"	"	"	146.5	0	0	20	0	314.5
"	9:00 "	"	"	"	143.0	0	0	25	0	307.0
Raw	2:00 "	9	----	----	186.0	0	10	39	54	385.5
"	6:00 "	"	----	----	186.0	0	15	39	49	385.5
Sedimen.	5:30 "	"	12.0	4.4	159.0	50.0	8	27	35	343.0
"	6:00 "	"	"	"	155.0	16.5	5	25	30	350.0
"	7:00 "	"	"	"	165.0	16.5	7	27	35	343.0
Filtrate	6:00 "	"	"	"	162.0	0	0	25	0	350.0
"	8:00 "	"	"	"	167.5	0	0	25	0	357.0

TABLE 1 (Cont.)

Kind of Water	Hour of collection	Date of Collection	Amt of lime.Gr. per gal	Rate of Filtr.Gal. per min.	Alk. to M. Orange. Parts per Million	Alk. to Phenol. Parts per Million	Turbidity. Parts per Mill.	Iron. Parts per Mill.	Color Parts per Mill.	Hardness Parts per Mill.
Raw	2:00p.m.	May 13	----	----	186.0	0	10	39	49	385.5
Sedimen.	5:00 "	"	8.0	3.95	128.0	23	5	25	30	300.0
Filtrate	8:30 "	"	"	"	130.0	19	0	25	0	300.0
"	9:30 "	"	"	"	134.0	15	0	20	0	307.0
Raw	1:30 "	15	----	----	185.0	0	10	39	49	385.5
Sedimen.	6:30 "	"	6.0	3.8	136.0	23	5	25	30	300.0
"	8:00 "	"	"	"	137.0	23	5	25	30	300.0
Filtrate	8:00 "	"	"	"	133.0	15	0	20	0	307.0
"	9:00 "	"	"	"	133.0	15	0	20	0	314.5
Raw	5:00 "	16	----	----	185.0	0	10	39	49	407.0
Sedimen.	5:30 "	"	5.0	3.7	138.0	12	5	25	25	314.5
"	7:30 "	"	"	"	140.0	15	5	25	25	328.5
Filtrate	7:30 "	"	"	"	142.0	0	0	25	0	328.5
"	8:30 "	"	"	"	140.0	0	0	25	0	321.5

TABLE SHOWING PERCENTAGE OF REMOVAL BY
SEDIMENTATION.

TABLE 2

Grains. per gallon, Lime	Rate. Mill.gal. per acre/day.	PERCENTAGE.				
		Alkali.	Turb.	Iron.	Color.	Hardness.
12	127.0	14.2	46.0	32.4	35.2	10.4
8	114.0	31.0	50.0	36.0	63.0	22.2
6	110.0	26.2	50.0	36.0	63.0	22.2
3	105.0	24.4	50.0	36.0	28.5	19.3

PERCENTAGE OF REMOVAL
BY SEDIMENTATION AND FILTRATION.

Lime Grains per gallon.	Rate in Mill.gal. per acre/day.	PERCENTAGE.		
		Alkalinity.	Iron.	Hardness.
12.0	127.0	12.5	36.0	8.3
11.6	114.0	19.6	42.2	25.2
9.2	126.0	13.0	30.8	9.6
8.0	114.0	29.0	42.2	21.3
6.0	110.0	28.0	48.5	19.4
3.0	105.0	23.75	36.0	20.25
* Turbidity and color were entirely removed.				

4. CONCLUSION.

Table 1 pages 10 and 11 shows the general results of the tests, and table 2 page 12 gives the percentage of removal by sedimentation, and by sedimentation and filtration.

With 12 grains of lime per gallon and 127 millions gallons per acre per day as rate of filtration, the percentage of removal of alkalinity by sedimentation as referred to the raw water was only 15; of turbidity 45; of iron 32 and of color and hardness were 35 and 10.3 respectively; while with 3 grains per gallon and 105 millions gallons per acre per day as rate of filtration, the removal of alkalinity was 24.4%, of turbidity 50 %, of iron 36 %, of color 28.5 % and hardness 19.3 %. With the exception in color the percentage of removal in the last case was higher than in the former. These two rates represented the maximum and minimum both of grains per gallon and rate of filtration. 8 grains per gallon with 114 millions gallons per acre per day seemed to be the best amount, as the percentage of removal in all cases was higher; viz.: in alkalinity the removal was 31 %, in turbidity 50 %, in iron 36, in color 63 %, and in hardness 22 %.

Turbidity and color were completely removed by the filter. The percentage of removal of alkalinity, iron and hardness by

sedimentation and filtration did not differ much from that by sedimentation alone. 11.6 grains per gallon and 114 millions gallons per acre per day as rate of filtration showed higher percentage of removal of hardness and iron, but low in alkalinity; and 8 grains per gallon with the same rate of filtration had better effect on alkalinity and iron but deficient in hardness. This variation of results together with the shortness of test make^{it} rather difficult to draw a very definite conclusion; but it seems to be safe to conclude that eight grains per gallon is the best amount for the treatment of this water.

The length of time for the treated water to pass thru the sedimentation basin was another factor that produced some effect. In the higher rate of filtration, such as 127 millions and 12 grains per gallon as the amount of coagulant, the treated water was calculated to remain in the sedimentation basin for eight hours, while in the lower rate, such as 114 millions gallons and eight grains per gallon, the treated water was estimated to remain in the tank for nine and one-half hours. The results under these two conditions varied to some extent; the longer the time of sedimentation the higher the percentage of reduction was.

It was desired to use shorter periods of sedimentation but owing to the clogging of the pipe leading to the sedimentation basin this was impossible.

The writer wishes to acknowledge his obligations to Prof. Bartow and Mr. L. I. Birdsall of the State Water Survey for their valuable suggestion in conducting the chemical analyses.

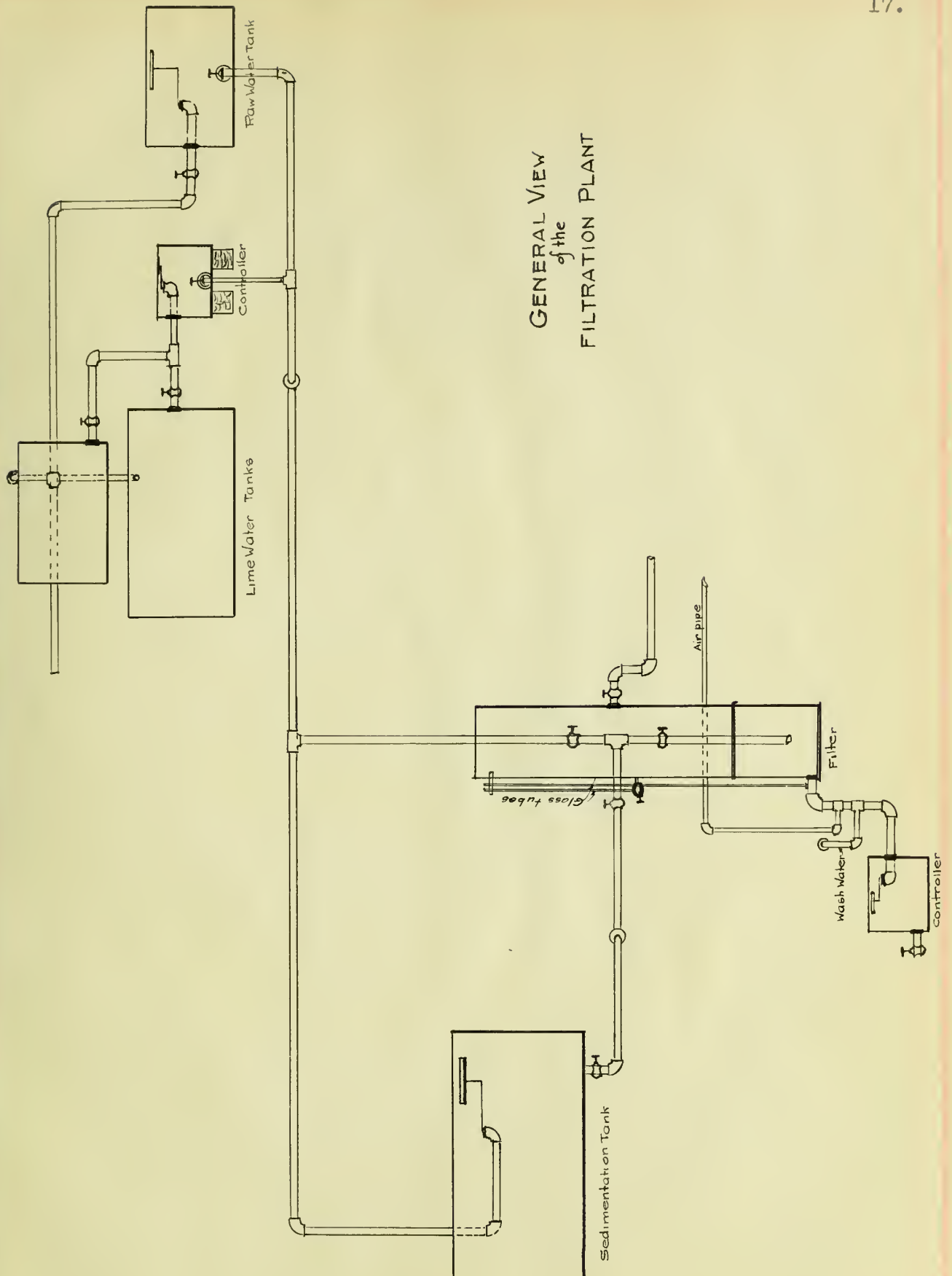


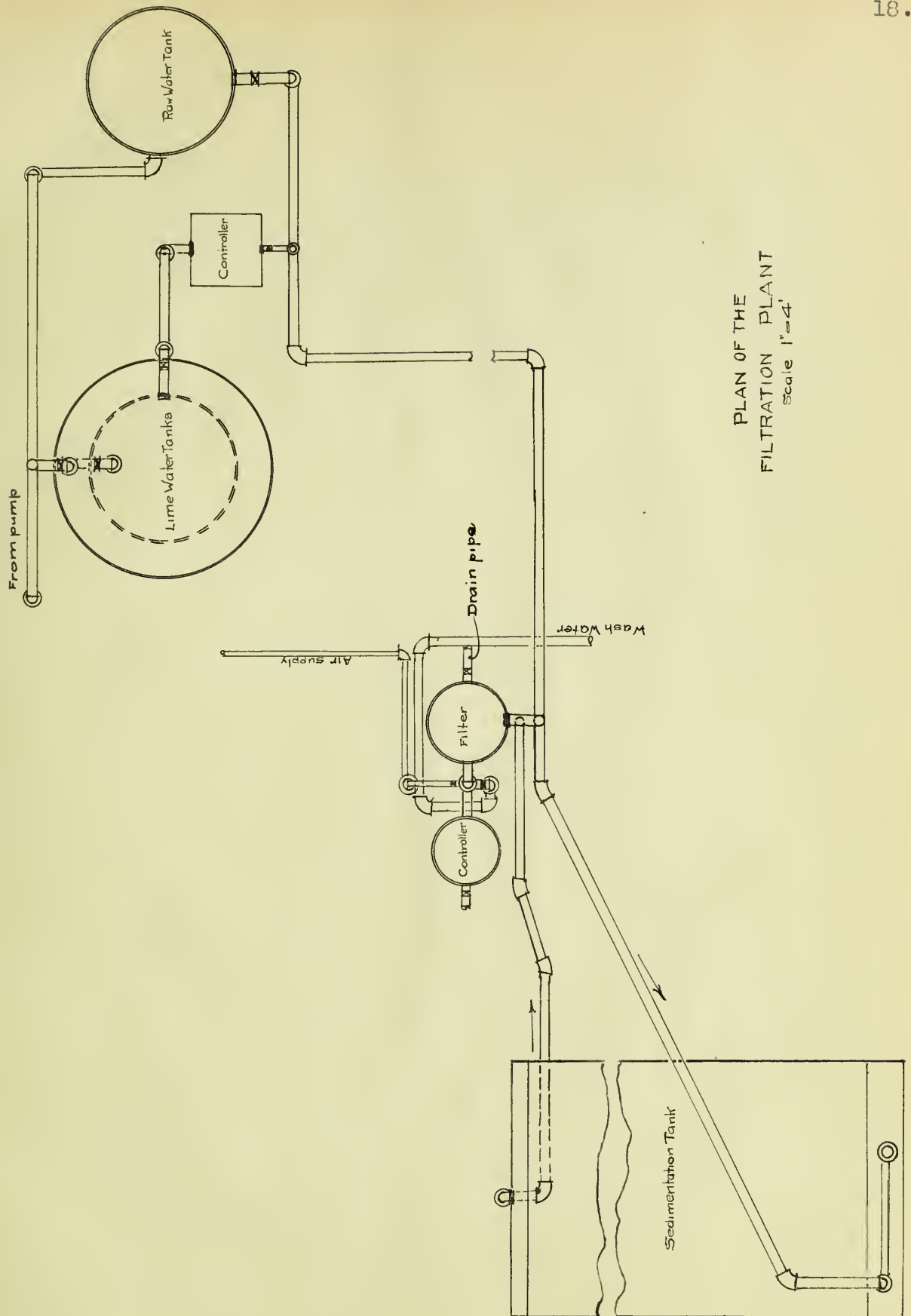
GENERAL VIEW OF FILTER.



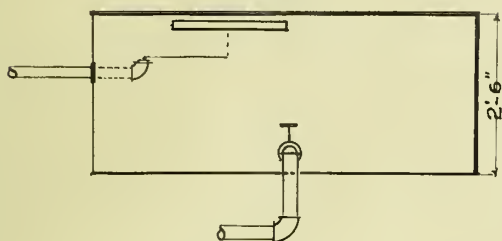
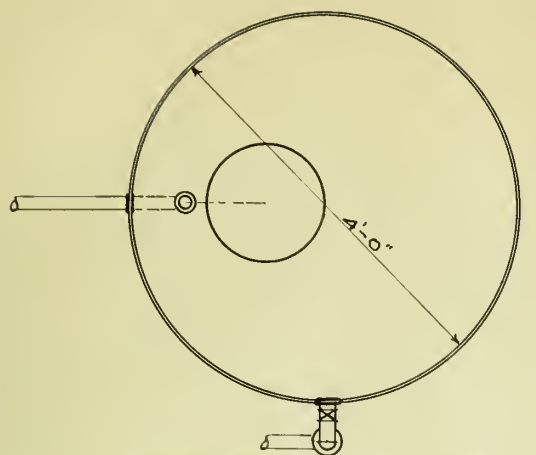
GENERAL VIEW OF SUPPLY AND
CHEMICAL TANKS.

GENERAL VIEW
of the
FILTRATION PLANT

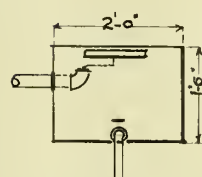
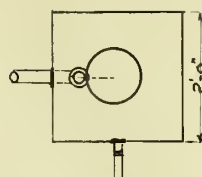




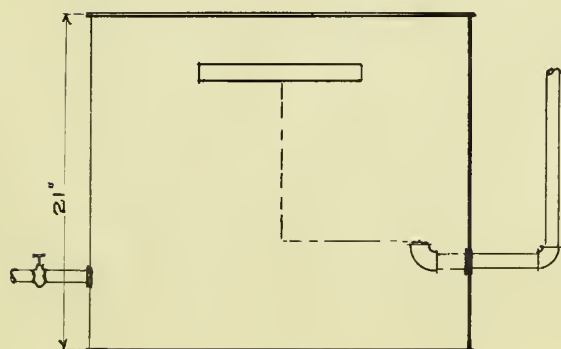
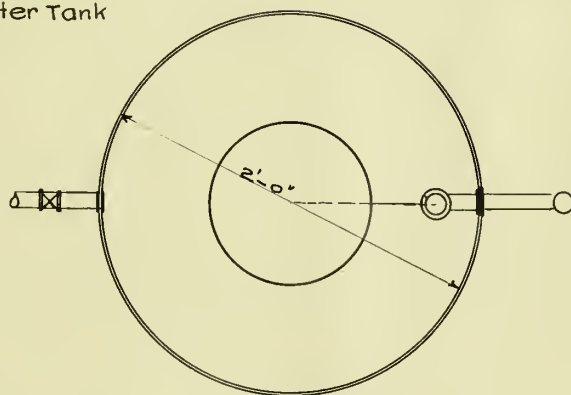
PLAN OF THE
FILTRATION PLANT
Scale 1"=4'



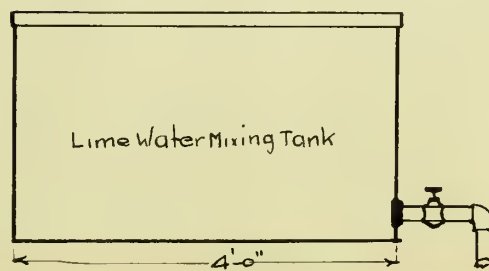
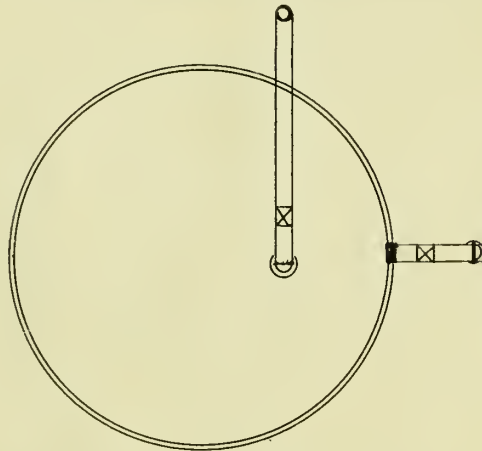
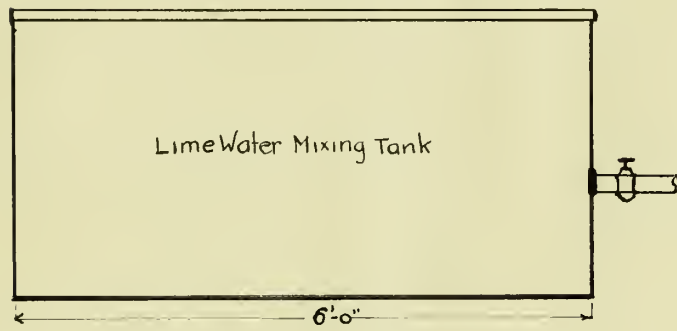
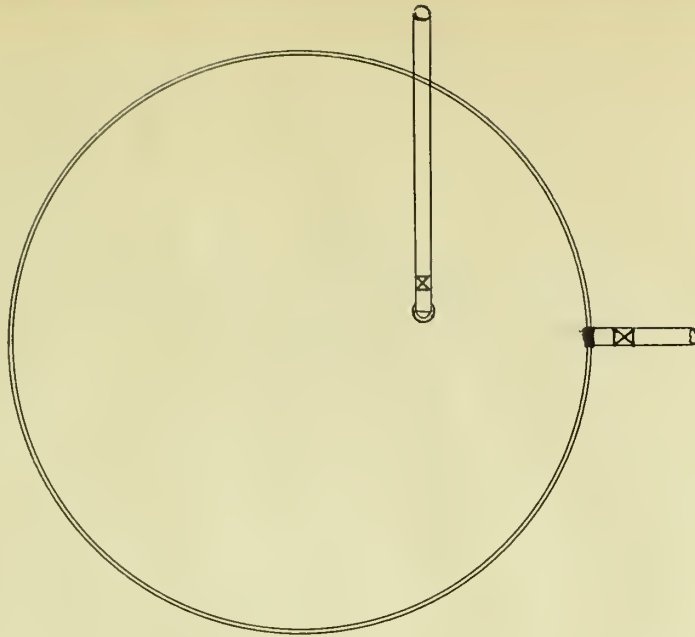
Raw Water Tank

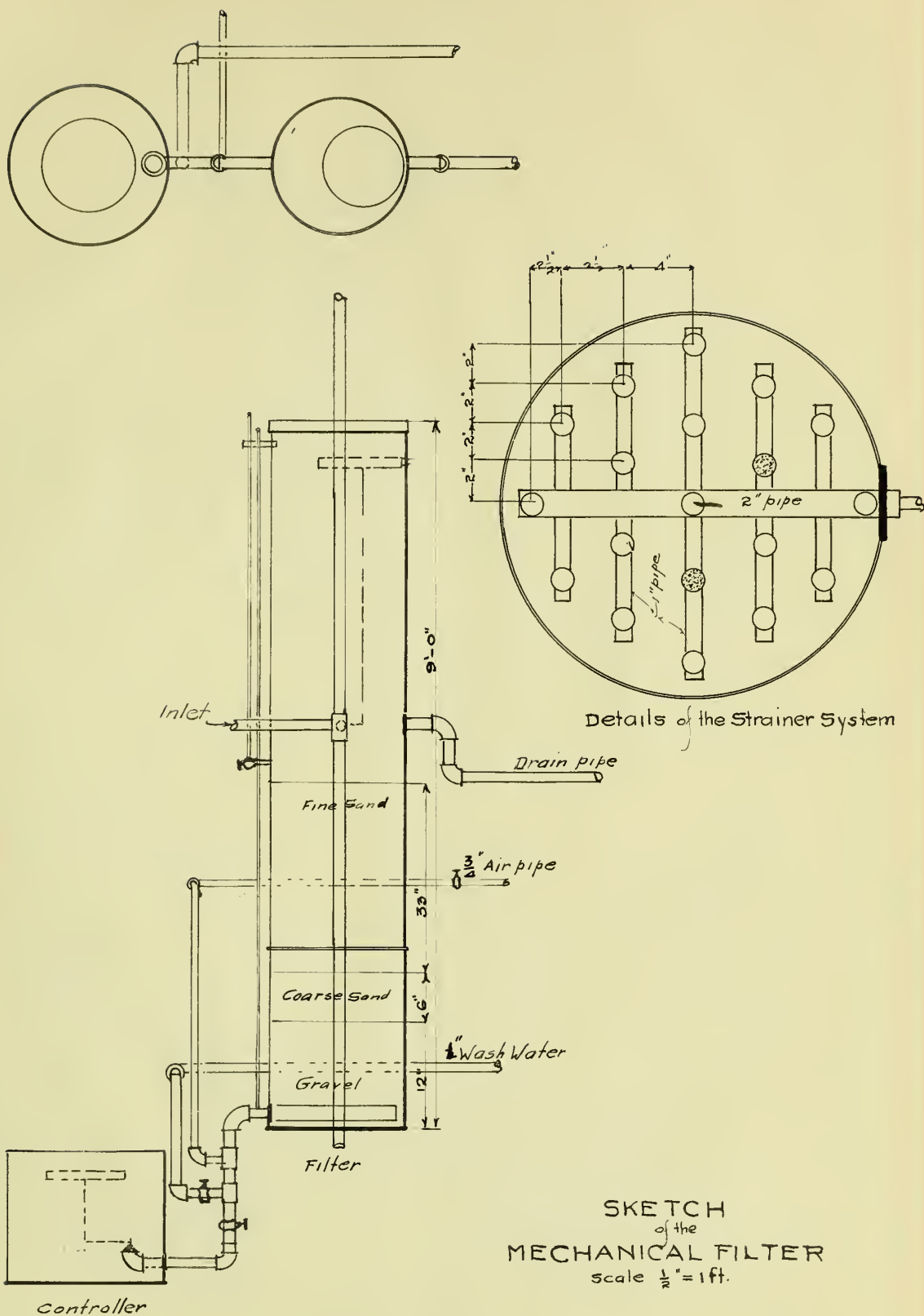


Lime Water Controller



Enlarged View of Clear Water Controller







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